# IMPROVED OPTICAL SWITCH AND NETWORKING METHOD

## BACKGROUND

**[0001]** The present invention relates to the art of data networks. More particularly, the present invention relates to data networks using optical switches.

**[0002]** Because of ever increasing bandwidth requirements, data networks utilizing optical transmission systems are becoming popular. Optical transmission systems have a larger bandwidth compared to electrical transmission systems.

**[0003]** Figure 1 illustrates a simplified optical switching network 100 including a plurality of input lines represented by lines 102a, 102b, and ellipsis 102c (collectively, "102") and a plurality of output lines represented by lines 104a, 104b, and ellipsis 104c (collectively, "104"). In the network 100, three optical nodes NA 110, NB 120, and NC 130 are illustrated. Although only three nodes are shown, the switching network 100 may include hundreds or even thousands of interconnected optical nodes.

**[0004]** Node NA 110 has an optical switch 112, a control circuit 114, and a plurality of input lines and output lines, or ports, designated, for convenience, NA0 to NA*n* where *n* is an integer. Typical values for n may be 15, 63, or 255. The ports – NA0, NA1, … and NAn – are ports of the node NA 110 as well as the ports of the switch 112. The switch 112 may utilize micro mirrors, liquid, or gaseous elements (generically, "switching element") to direct or reflect optical signals from a first port to a second port. Typically, the ports are bi-directional but is sometimes uni-directional. The control circuit 114,

connected to the switch 112, controls the state of the switching elements to implement Node NA 110 as described herein above is known in the art.

**[0005]** Nodes NB 120 and NC 130 are similarly configured to node NA 110, and their ports are similarly denoted herein. A path router 140 is connected to nodes NA 110, NB 120, and NC 130. The path router 140 contains physical path topology of the network 100 necessary to make connections as requested. The path router 140 contains the physical network topology of how the switches are connected.

**[0006]** For instance, in order for the path router 140 to successfully direct an input signal at input line 102b to an output line 104b, the path router 140 needs to know that (1) the input line 102b feeds into port ~~NA7~~ NA1; (2) port NA9 is connected to port NB1; (3 port) NB8 is connected to port NC7; and (4) port NC9 is connected to the output line 104b. With the information, the path router 140 signals node NA 110 to route its port NA~~7~~1 to its port NA9, signals node NB 120 to link its port NB1 to its port NB8, and signals node NC 130 to link its port NC7 to its port NC9. The physical path topology information may be entered directly into the path router 140 or supplied by an external controller system (not shown), connected to the path router 140.

**[0007]** In the illustrated configuration, port NA9 is connected to port NB1 (connection 150) and port NB8 is connected to port NC7 (connection 152). The other ports of nodes NA 110, NB 120, and NC 130 may be connected to ports of nodes not show in Figure 1. As the number of nodes, thus the ports, grows in the network 100, the number of possible connections grows exponentially. It is not uncommon to have a network with hundreds or even thousands of ports. Prior art requires that the physical topology be configured

manually.

[0008] Without a correct topology of the network 100 as defined by the connection information of the routing table, the network 100 does not operate effectively.

[0009] The processes of manually defining the full network physical path topology for the path router 140 are susceptible to error. For example, an optical path can be made to an unintended port or to an unintended node. Or, incorrect data may be entered into the path router 140. The problem is exacerbated by the fact that networks are becoming increasingly large and complex.

[0010] Moreover, when new nodes are installed, connections are modified, or when error in connection information is suspected, the entire network must be manually analyzed, and the topology manually reconfigured. No dynamic or automated procedure exists to determine the network topology.

[0011] Accordingly, there remains a need for an improved technique to determine the connections and topology of an optical network.

## SUMMARY

[0012] These needs are met by the present invention. According to one aspect of the present invention, an apparatus has an optical switch for routing optical signals, the optical switch including ports. The apparatus also includes a light source, a light detector, and a control circuit connected to the optical.

[0013] According to a second aspect of the invention, an optical network including a plurality of optical nodes is disclosed. A node includes an optical switch for routing optical signals, the optical switch including

ports. Further, the node has a light source, a light detector, and control circuit connected to the optical switch.

**[0014]** According to a third aspect of the invention, a method of determining topology of a network is disclosed. First, connection information of a first port of a first node is determined. Then, a path router is updated with the connection information.

**[0015]** According to a fourth aspect of the invention, a method of discovering an optical interconnect path is disclosed. First, a first identification is sent from a first port of a first node. Then, the first identification is received at a first port of a second node. The interconnect path is the between the first port of the first node and the first port of the second node.

**[0016]** Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in combination with the accompanying drawings, illustrating by way of example the principles of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0017]** Figure 1 is a simplified illustration of an optical network including prior art optical nodes; and

**[0018]** Figure 2 is a simplified illustration of an optical network according to one embodiment of the present invention.

## DETAILED DESCRIPTION

**[0019]** As shown in the drawings for purposes of illustration, the present invention is embodied in an optical node apparatus having an optical switch for routing optical signals, the optical switch including

ports. The apparatus also includes a light source, a light detector, and a control circuit connected to the optical switch. The optical node sends its node identification via each of its ports, and also listens to each of its ports to detect node id's from other optical nodes connected to the optical node.

**[0020]** Referring to Figure 2, an optical network 200 includes a plurality of optical nodes. For brevity, only three nodes are shown in Figure 2. They are, node ND 210, node NE 220, and node NF 230. The network 200 includes a plurality of input lines represented by lines 202a, 202b, and ellipsis 202c (collectively, "202") and a plurality of output lines represented by lines 204a, 204b, and ellipsis 204c (collectively, "204"). Although only three nodes are shown, the switching network 200 may include hundreds or even thousands of interconnected optical nodes.

**[0021]** Node ND 210 has an optical switch 212, a control circuit 214, and a plurality of input lines and output lines, or ports, designated, for convenience, ND0 to ND*n* where *n* is an integer. Typical values for n may be 15, 63, or 255. For brevity, the ports of node ND 210 are referred to, collectively, as ports 211. For the illustrated embodiment, the ports 211 are ports of node ND 210 as well as ports of the switch 212. The switch 212 may utilize micro mirrors, liquid, or gaseous elements (collectively, "switching element") to direct or reflect optical signals from a first port to a second port.

**[0022]** A light source 216 is connected to one of the ports 211 of the switch 212. The light source 216 may be modulated to produce a light signal, which may be routed to any of the ports of the switch 212. A light detector 218 is connected to another port of the switch 212. The light detector 218 may be connected

to any of the ports 211 of the switch 212 to detect light signal on the connected port. In the current technology, light sources may be implemented using or laser diodes. The light detectors may be implemented as photodiodes or phototransistors for example. Semiconductor light sources and detectors are well known in the industry and can be easily obtained from various manufacturers, for example, Agilent Technologies, Inc.

**[0023]** The control circuit 214, connected to the switch 212, controls the state of the switching elements to implement routing of the optical signals from a first port to a second port. For instance, the control circuit 214 may cause the switch 212 to connect port ND1 to port ND9 to route an incoming optical signal from line 202b, connected to port ND1, to be routed to port ND9 for forwarding to port NE1 of node NE 220.

**[0024]** The control circuit 214 may include a node id (for example, "ND") for node ND 210. Preferably, the node id uniquely identifies node ND 210 within the network 200. The control circuit 214 is also connected to the light source 216 and the light detector 218. Alternatively, the node id may be supplied by the path router as needed. The node id may further include a port identification portion that identifies the port (of the node) through which the communication is taking place.

**[0025]** Node NE 220 is similarly configured to node ND 210 and has switch 222, ports NE0 through NE*N* (collectively, ports 221), light source 226, light detector 228, and control circuit 224. The control circuit 224 is connected to the switch 222, the light source 226, and the light detector 228, and has a node id (for example, "NE") for node NE 220.

**[0026]** The technique of determining the topology, or the

connection information, of network 200 can be explained using nodes NE 220 and ND 210. Control circuit 224 causes light detector 226 to produce optical signals ("identification signal") identifying node NE 220 such as signal corresponding to node id "NE". The identification signal may be sent to each of the ports 221 by routing, using switch 222, the identification signal to each of the ports 221. Preferably, the identification signal also includes information regarding which port of node NE 220 the identification signal is being sent from.

**[0027]** The identification signal is received by node ND 210. Control circuit 214 of node ND 210 causes light detector 218 to receive optical signals from each of ports 211 of node ND 210. When light detector 218 is connected to port ND9, light detector 218 receives the identification signal from port NE1 of node NE 220. The received identification signal is forwarded to control circuit 214. With the received identification signal, control circuit 214 recognizes that its port ND9 is connected to port NE1 of node NE 220 and stores this connection information, forwards the connection information to a path router 240 to update the path router 240, or both. The connection is illustrated by connection 250 in Figure 2. Additionally, control circuit 214 may send the connection information to another node, not shown, such that the other node is informed about the connection 219.

**[0028]** Based on the available paths, the path router 240 can then make optical path connections as requested. The path router 240 may include the following components: (1) information on the physical path topology; (2) Switch configuration (number of ports, etc.); and (3) current list of requested optical path connections including dynamic requests to change

optical paths. These requests need not know the physical topology of the network but rather specification of the endpoint to endpoint connection. The path router 240 maps the optical path connection requests to physical switch changes based upon the physical topology. The word "connection" includes, without limitation, relatively static port to port switch connections as well as the physical network topology, or how the switches are physically connected.

**[0029]** The process also works in reverse. That is, node ND 210 sends its node identification "ND" via its ports 211 as identification signal. When the identification signal is sent on port ND9, node NE 220 detects the identification signal, recognizes that its port NE1 is connected to port ND9 of node ND 210, and stores this connection information. The connection information is then reported to the path router 240.

**[0030]** Therefore, under the present invention, the topology of the network is dynamically determined using self-identifying nodes such as node ND 210 and node NE 220. In one embodiment of the present invention, all nodes of the network 200 are similarly configured to illustrated nodes ND 210 or NE 220. However, this is not required. In the network 200, node NF 230 does not include a light source or a light detector; however, its route topology may be manually entered into the path router. In the case that such node is connected to nodes with node identification capability, such topology may be found.

**[0031]** The connection information detection may be performed for unused ports. That is, for the ports for which no connection information exists. Alternatively, the connection information detection may be performed even for used ports using supervisory

channels or bands.

**[0032]** The path router 240 may maintain the connection information in a routing table. Alternatively, the connection information may be maintained in a distributed manner by the nodes themselves.

**[0033]** From the foregoing, it will be appreciated that the present invention is novel and offers advantages over the current art. The present invention results in an automatic determination of connection information in an optical network, the connection information being less susceptible to errors. Although a specific embodiment of the invention is described and illustrated above, the invention is not to be limited to the specific forms or arrangements of parts so described and illustrated. For example, each optical node such as node ND 210 may include a plurality of light sources, a plurality of light detectors, or both. Alternatively, light source 216 may be built outside the node 210 with the identification signals being sent to the node via one of the ports. Likewise, light detector 218 may be located outside the node 210 with the light signals being sent out to the external light detector for processing. The invention is limited only by the claims that follow.